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Deep planting improved stem root growth, flower yield and quality of *Lilium* cultivars

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ABSTRACT

Lily species are considered one of the most important cut flowers worldwide. With annual production of 282 million flowers and total value of $200 million, lily is among the top five cut flower species auctioned in the international flower stock markets. The objective of this study was to assess the effect of different planting depths on morphology, physiology, root growth and flower quality of lilies. Three hybrid lilies [*Lilium* × *elegans*; Orienpet ('Maytime', white) and L.A. ('Fangio', pink and 'Pavia', yellow)] were used. Deep planting at 25 cm significantly improved total and stem root systems, stem diameter and leaf area. No significant differences were noticed between planting depths for plant height, chlorophyll content, and gas exchange (photosynthesis, stomatal conductance and transpiration). Flower quality variables, specifically, vase life from deep planting were higher in 25-cm compared to 5 and 15. The 'Maytime' cultivar had higher leaf area, total and stem roots, flower diameter, number of days to flowering, and brighter color (L*) while the 'Fangio' had higher leaf number per plant, more basal roots, flower number per plant, vase life, and red color coordinate (a*). Overall, our results revealed that lily growers can increase their lily flower quality by adopting the deep planting at 25 cm.

Keywords: *Lilium* × *elegans*, flower color; vase life; planting depth.

RESUMO

Plantio profundo melhorou o crescimento das raízes do caule, rendimento de flores e a qualidade das cultivares de *Lilium*

As espécies de lírio são consideradas uma das flores de corte mais importantes do mundo. Com produção anual de 282 milhões de flores e valor total de US$ 200 milhões, o lírio está entre as cinco principais espécies de flores de corte leiloadas nas bolsas internacionais de flores. O objetivo deste trabalho foi avaliar o efeito de diferentes profundidades de plantio na morfologia, fisiologia, crescimento radicular e qualidade floral de lírios. Três lírios híbridos foram avaliados [*Lilium* × *elegans*; Orienpet ('Maytime', branco) e L.A. ('Fangio', rosa e 'Pavia', amarelo)]. O plantio profundo a 25 cm melhorou significativamente o sistema radicular total e do caule, o diâmetro do caule e a área foliar. Não foram observadas diferenças significativas entre as profundidades de plantio para altura de planta, teor de clorofila e trocas gasosas (fotossíntese, condutância estomática e transpiração). As variáveis de qualidade da flor, especificamente, a vida de vaso do plantio profundo foi maior em 25 cm comparado a 5 e 15. A cultivar 'Maytime' apresentou maior área foliar, quantidade de raízes totais e do caule, diâmetro da flor, número de dias para floração e cor mais brilhante (L*) enquanto a 'Fangio' apresentou maior número de folhas por planta, raízes basais, número de flores por planta, vida de vaso e coordenada de cor vermelha (a*). No geral, nossos resultados revelaram que os produtores de lírio podem melhorar a qualidade da flor de lírio adotando o plantio profundo a 25 cm.

Palavras-chave: *Lilium* × *elegans*, cor da flor; vida em vaso; profundidade de plantio.

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The lily (*Lilium* spp.) family contains more than 100 species (Dole & Wilkins, 2005). Numerous hybrids and cultivars are grown as field and greenhouse-grown cut flowers for regular production year-round. Summer induces floral initiation, making most lilies a facultative long-day plant (Dole & Wilkins, 2005). Commercially, lily mainly produces in greenhouse conditions and the temperature requirement ranged from 10 to 17°C at night and 16 to 21°C at daytime (Hertogh, 2000; Dole & Wilkins, 2005).

Lily is one of the top five cut flower species auctioned in flower stock markets. The Royal FloraHolland which is one of the largest auction organizations in the world sold about 282 million lily flowers in 2019 (Statista, 2019). Cultural practices such as nutrient management, growing substrate selection and exogenous hormones application have significantly affected lily growth, physiology, and flower quality (Al-Ajlouni *et al.*, 2017; A'saf *et al.*, 2020; Othman *et al.*, 2021). For example, using 0-4 mm tuff substrate improved growth and flower quality of *Lilium* × *elegans* (cvs. Fangio and Ercolano) grown under soilless culture compared to 0-2 and 0-8 mm (Al-Ajlouni *et al.*, 2017).

Root system is an essential underground part of terrestrial plants. Root system controls the entire plant growth signals to aboveground organs, including cytokinins, auxins, abscisic acid, and adjusts plant growth processes such as stomatal behavior, leaf expansion, and induction of photosynthetic enzymes (Aiken & Smucker, 1996). Therefore, a strong root system is vital to guarantee proper growth and development of the shoot as well as higher yield (López-Bucio *et al.*, 2003; Song, 2017). In lily, the root system composes of normal (basal) and stem root systems. Both root types are located below the soil surface. The basal ones are fleshy and grow at the basal plate under the bulb, whereas the stem roots are the fibrous roots (underneath the soil) between the base of the shoot and the top of the bulb (Song, 2017). Stem root system plays an essential role in the growth and development of lily shoots while the basal roots did not affect lily growth to a significant level (Song, 2017). Overall, improving root system of lily especially, the stem roots will enhance growth and productivity and consequently increase profit for cut flower growers.

Planting depth, specifically deep planting has improved growth and productivity of several species including, *Lilium*, *Crocus, Curcuma,* and *Colocasia* (Spencer & Ksander, 1990; Amjad & Ahmad, 2012; Koocheki & Seyyedi, 2019). Deeper planting (30 cm) of taro (*Colocasia esculenta*) produced higher corm yield and length than that of 15 cm (Tumuhimbise, 2015). The turmeric shoot dry weight and rhizome (yield) from 16 cm soil depth developed earlier than at 4 cm. In addition, 30% of turmeric from 4 cm soil depth was uprooted by a typhoon, but not at 16 cm (Ishimine *et al.*, 2003). Interestingly, tuber infestation by potato tuber moth (*Phthorimaea operculella*) was significantly reduced (50%) by planting potato seed 25 cm below the ridge apex rather than the standard 18 cm (Foot, 1976). However, in asparagus (*Asparagus officinalis*) yield and quality of spears decreased with soil depth (5, 10, 15, 20 cm). Overall, planting depth hold promise for improving growth and productivity of several species.

Lily bulbs are grown in a wide range of soil or soilless media types including peat-moss, tuff and cocopeat (Al-Ajlouni *et al.*, 2017; Othman *et al.*, 2021). However, the addition of aggregates such as perlite to growing media is recommended to improve drainage and aeration. Commercially, 30 to 90 bulbs can be planted per m^2, depending on bulb size and species. In addition, the bulbs should be planted at least 5 cm below the surface of the medium to encourage stem roots (Hertogh, 2000; Dole & Wilkins, 2005). Amjad & Ahmad (2012) found that higher planting density (10 cm space between bulbs) and deeper lily (*Lilium longifolium*) bulb planting at 15 cm resulted in higher leaf area, chlorophyll content than those grown in shallow soil depth at 7.5 cm and low density in 60 cm. Assessment of proper management practices to improve lily growth, flower quality and yield is not new. However, few studies have included leaf gas exchange analysis [photosynthesis (P_n), stomatal conductance (g_s) and transpiration (E)] as an aid to understand the leaf-level physiology of lily plants (Chang *et al.*, 2008; Othman *et al.*, 2021). In addition, no study we are aware of has assessed the effect of planting depth on stem roots and flower quality (color, diameter, number per plant) of lily cultivars. We hypothesized that deep planting can increase stem root system, enhance plant physiology and consequently improve flower quality and productivity of lilies.

Therefore, the objective of this study was to assess the effect of different planting depth on morphology, physiology, root growth and flower quality of lily, Orienpet ('Maytime') and L.A. ('Fangio' and 'Pavia').

MATERIAL AND METHODS

Site description, plant material and treatments

The experiments were conducted in a greenhouse at the Department of Horticulture and Crop Science, University of Jordan, Amman, Jordan, between November 5, 2019 and March 15, 2020. Three hybrid lilies [(*Lilium × elegans*); Orienpet ('Maytime', white, fragrant) and L.A. non-fragrant ('Fangio', pink and 'Pavia', yellow)] were used. *Lilium × elegans* is the hybrid of *Lilium maculatum × Lilium pensylvanicum*. Orienpet hybrid lilies are the result of crossing Oriental lilies with Trumpet type. L.A. hybrids are a cross between *Longiflorum* lilies and Asiatic hybrids. The bulb diameter of 'Fangio' was about 5-6 cm, 'Pavia' 4-5 cm and 'Maytime' from 6-7 cm. Because lily has imbricate bulb type (does not have the tunic, papery covering to protect the fleshy scales from drying), the bulbs were kept moist in peatmoss and stored at 0-4°C before planting. The tunnels depth for hydroponic systems is about 20 cm and the planting depth that lily growers adopt ranged from 5 to 15 cm. The recommended planting depth in commercial cut flower nurseries and previous studies ranges from 7 to 20 cm (Amjad & Ahmad, 2012). In this study, three lily bulbs were transplanted into a 25 L plastic pot (diameter 30 cm, depth 36 cm) filled with growing medium (3:1:1 peatmoss-perlite-clay soil). Growing media pH was 6.4 and electrical conductivity was 0.2 ds m^{-1}. The pots were placed in a bench (6×3 m) in the greenhouse. Irrigation was conducted manually twice a week. Fertigation was applied weekly using commercial fertilizer 20N-20P_2O_5-20K_2O at rate of 150 N, 65 P and 125 K mg L^{-1} during vegetative stage and using 20N-20P_2O_5-30K_2O and potassium chloride at rate of 100 N, 44 P and 200 K mg L^{-1} from early flowering to harvesting. Mean minimum and maximum temperatures in the greenhouse were 13±1°C and 19±3°C, respectively, and light intensity during the daytime was on average 185±25 µmol s^{-1} m^{-2}. During the experimental period, the three planting depths 5, 15 and 25 cm and three lily cultivars ('Maytime', 'Fangio' and 'Pavia') were evaluated.

Plant morphology and physiology

Plant physiology variables [gas exchange (P_n, E, and g_s) and chlorophyll content] were determined at vegetative and flowering (harvesting) stages while plant morphology (plant height, stem diameter, leaf number and area, root fresh weight) and flower quality were carried out at harvesting. Physiological measurements were conducted between 1100 and 1300 HR (Leskovar & Othman, 2018). Chlorophyll content was determined on the middle and flag leaves using a chlorophyll concentration meter (MC-100; apogee Instruments, North Logan, UT, USA). The detector MC-100 analyzes the ratio of two wavelengths to determine chlorophyll content index not concentration of chlorophyll *a*, *b* or *a*+*b*. Gas exchange was determined from two fully expanded sunny-exposed leaves with a portable photosynthesis system (LI-6400XT; LI-COR, Lincoln, NE, USA). Light intensity was set to track ambient photosynthetically active radiation, reference carbon dioxide to 400 μmol, flow rate to 500 μmol s^{-1}, and chamber head to 6 cm^2 (Leskovar & Othman, 2021). Following the commercial practices, harvesting stage was when one of the flowering buds began to open but not fully opened (Othman *et al.*, 2021). At harvesting stage, plant morphology (plant height, leaf area and stem diameter) was determined. Total leaf area per plant was measured using a leaf area meter (AM350; ADC BioScientific, Hoddesdon, UK). Flowering stems (shoot) were cut from the basal point for flower quality assessment. Basal roots and stem roots were washed from growing substrate to determine fresh weight.

Flower quality

Flower quality variables (number of days to flowering, flower diameter, number per stem, vase life and color coordinates) were determined during flowering (harvesting) stage. Eight cut flowers per treatment were collected for post-harvest evaluation. These cut flowers were in the same phase, early blooming of the first bud. The number of days to flowering was from the day of planting (day 1) to the blooming of first bud on each stem plant (Al-Ajlouni *et al.*, 2017). Flower color was measured on intact petals as described in Schulze & Contreras (2017) and Alsmairat *et al.* (2018) using a colorimeter (CR-400, Konica Minolta, Ramsey, NJ, USA). Petal color coordinate L* represents the brightness level of the color [0 (black) to 100 (white)], a* is the positive/negative correlation to the red/green component [-80 (green) to +80 (red)], and b* is the yellow/blue component of color [-80 (blue) to +80 (yellow)] (Schulze & Contreras, 2017). During postharvest assessment, all tested stems had similar length (70 cm long) across cultivars and depth treatments. In addition, the total number of leaves for 'Maytime', 'Fangio' and 'Pavia' were 22±3, 38±4, 48±4, respectively. For vase life, stems were recut (2.5 cm from the base) in water and placed directly in commercial (Spring Pro-Florist, Spring from Holland B.V., Sassenheim, Nederland) preservative solution (2% sugar + fungicide, pH 3.5-4.0). Cut flowers are normally placed in preservative solution and not in the water to reduce the development of fungus and bacteria in the solution. Vase life was determined by measuring the number of days from harvesting, day to the first lily flower/per stem had fallen off or wilt (Othman *et al.*, 2021).

Experimental design setup and statistical analysis

A randomized complete block

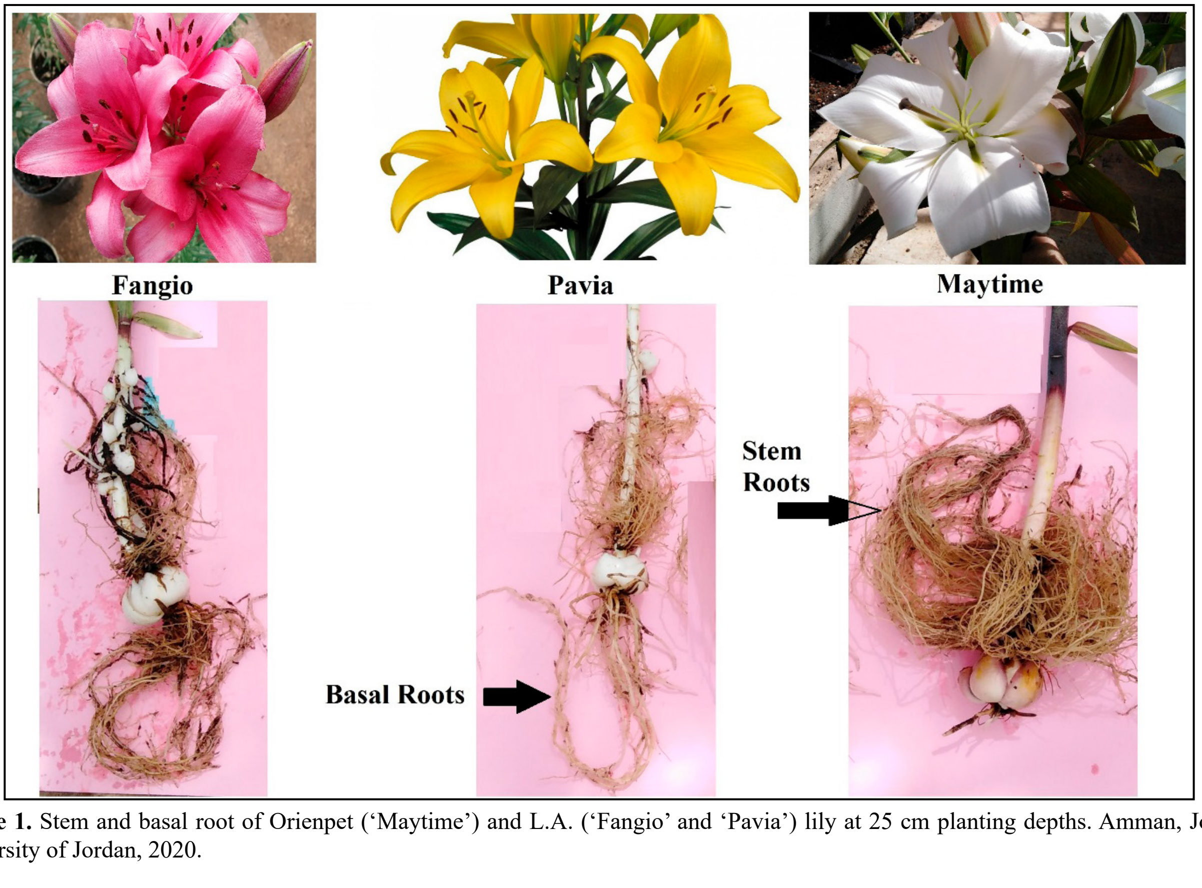

Figure 1. Stem and basal root of Orienpet ('Maytime') and L.A. ('Fangio' and 'Pavia') lily at 25 cm planting depths. Amman, Jordan, University of Jordan, 2020.

design (RCBD) with two factors (three planting depths and three cultivars) and four replications (three bulbs per pot, total twelve per treatment) was used. The analysis of variance (ANOVA) and the Tukey's HSD test ($P \leq 0.05$) in SAS (Version 9.2 for Windows; SAS Institute, Cary, NC) were used to identify differences between planting depth, cultivars and planting depth × cultivar interaction.

RESULTS AND DISCUSSION

Plant morphology and physiology

In this study, planting depth significantly affected plant morphology, specifically leaf area and stem diameter (Table 1). Bulbs planted at 25 cm depth had higher leaf area and stem diameter compared to shallow planting at 5 cm. In addition, 'Maytime' had higher plant height, leaf area, stem diameter and chlorophyll content at vegetation (middle and flag leaf) and flowering stages (middle leaf). Flowers with large glossy green leaves are attractive to customers and therefore considered an essential visual factor used to determine the quality of Lilium spp. (Othman *et al.*, 2021). In fact, leaf size, number and greenness are critical for lily flower visual appearance and consequently, marketing potential. Overall, deep planting depth at 25 cm improved leaf visual appearance by increasing their leaf area.

The direct physiological measurement to assess leaf greenness is chlorophyll content. Chlorophyll is vital for photosynthesis process in the leaf because the green pigments provide the required reaction energy for this metabolism process by absorbing energy from light (Wen *et al.*, 2018). However, no significance was found between planting depth for leaf chlorophyll content (Table 1). Photosynthesis is critical for plant growth, and productivity and can

Table 1. Plant height, leaf number, total leaf area per plant, stem diameter, chlorophyll content (chl-c), photosynthesis rate (P_n), stomatal conductance (g_s) and transpiration (E) of Orienpet ('Maytime') and L.A. ('Fangio' and 'Pavia') lily under different planting depths. Amman, Jordan, University of Jordan, 2020.

Main effect	Morphology			
	Flowering stage			
	Height (cm)	Leaf (no. plant^{-1})	Leaf area (cm^2 plant^{-1})	Stem diameter (mm)
Depth (D)				
5 cm	113	52.9	88.5 b	7.27 b
15 cm	113	51.5	106 a	7.60 b
25 cm	103	55.0	108 a	8.63 a
Cultivar (C)				
Maytime	149 a	46.8 b	160 a	9.27 a
Fangio	104 b	59.0 a	70.0 b	7.38 b
Pavia	76.3 c	53.7 a	71.7 b	6.86 c
P-value				
D	0.15	0.456	0.004	<0.0001
C	<0.001	0.001	<0.001	<0.0001
D×C	0.357	0.289	0.057	0.571

Table 1 continuation

Main effect	Physiology							
	Vegetative stage				Flowering stage			
	Chl-c (µmol m^{-2})	P_n (µmol m^{-2} s^{-1})	g_s (mol m^{-2} s^{-1})	E (mmol m^{-2} s^{-1})	Chl-c (µmol m^{-2})	P_n (µmol m^{-2} s^{-1})	g_s (mol m^{-2} s^{-1})	E (mmol m^{-2} s^{-1})
Depth (D)								
5 cm	446	19.8	0.16	3.27	242	16.5	0.19 a	2.84
15 cm	436	20.1	0.16	3.51	225	16.8	0.12 b	2.29
25 cm	427	19.8	0.14	2.88	244	17.2	0.14 b	2.38
Cultivar (C)								
Maytime	521 a	19.6	0.12 b	2.66 b	232 b	16.6	0.14 ab	2.43
Fangio	414 b	19.9	0.17 a	3.36 ab	275 a	16.9	0.13 b	2.28
Pavia	374 b	20.1	0.18 a	3.65 a	204 b	17.1	0.18 a	2.81
P-value								
D	0.45	0.61	0.38	0.21	0.53	0.65	0.04	0.17
C	0.01	0.36	0.006	0.03	0.04	0.76	0.05	0.21
D×C	0.09	0.88	0.364	0.068	0.21	0.91	0.07	0.16

Values in columns followed by different letters indicate significant differences between treatments according to Tukey's HSD test ($P \leq 0.05$).

Table 2. Stem and basal root and bulb fresh weight (FW) of Orienpet ('Maytime') and L.A. ('Fangio' and 'Pavia') lily under different planting depths. Amman, Jordan, University of Jordan, 2020.

Main effect	Total roots (g/ plant)	Stem roots FW (g/plant)	Basal roots FW (g/ plant)	Stem roots FW (% of total root)	Bulb FW (g/ plant)
Depth (D)					
5 cm	34.80 b	21.8 c	13.0 a	46.0 c	37.2
15 cm	36.43 b	30.0 b	6.43 b	60.0 b	39.4
25 cm	58.29 a	50.5 a	7.79 b	68.0 a	40.7
Cultivar (C)					
Maytime	94.03 a	87.8 a	6.23 b	92.0 a	57.3 a
Fangio	22.38 b	9.28 b	13.1 a	42.0 b	37.0 b
Pavia	13.20 b	5.28 b	7.92 b	40.0 b	22.9 c
P-value					
D	<0.0001	<0.0001	<0.0001	<0.0001	0.26
C	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
D×C	0.18	<0.0001	0.09	0.28	0.16

Values in columns followed by different letters indicate significant differences between treatments according to Tukey's HSD test (P≤0.05).

potentially be affected by management practices such as irrigation, nutrient and hormonal application (Ayad *et al.*, 2018; Leskovar & Othman, 2018; Wen *et al.*, 2018). Interestingly, the allocation of biomass to photosynthetic tissues and flowers is affected by the initial planting depth (Spencer & Ksander, 1990). However, no significant difference in gas exchange (P_n, g_s and E) was found between planting depth across the vegetative and flowering stages (Table 1).

The root system of lily flowers connects supplies between the soil and shoot and therefore, a strong root system can result in an increase of shoot growth and development (Song, 2017). However, the root system in lily is unique compared with other cut flowers because it composes of basal and stem root systems which are located below the soil surface. The stem root system starts to grow rapidly when shoot emerges from the soil. At this early stage of stem root development, the bulb is the main food supplier for the stem root system but after shoot begins to grow, the stem roots become the main source of soil nutrients and water for the plant (Song, 2017). In this study, deep planting at 25 cm significantly increased total and stem roots fresh weight and reduced basal root (Table 2 and Figure

Table 3. Flower quality components of Orienpet ('Maytime') and L.A. ('Fangio' and 'Pavia') lily under different planting depth. Amman, Jordan, University of Jordan, 2020.

Main effect	Flower (no/plant)	Flower diameter (cm)	No. of days to Flowering	Vase life (day)
Depth (D)				
5 cm	3.92 b	16.5	95.7	11.6 c
15 cm	4.17 ab	16.6	93.7	12.8 b
25 cm	4.58 a	16.6	96.2	13.8 a
Cultivar (C)				
Maytime	3.25 c	18.3 a	113 a	11.4 c
Fangio	5.17 a	15.6 b	76.3 c	14.1 a
Pavia	4.25 b	15.7 b	96.0 b	12.7 b
P-value				
D	0.05	0.91	0.489	<0.0001
C	<0.0001	<0.0001	<0.0001	<0.0001
D×C	0.24	0.72	0.21	0.008

Values in columns followed by different letters indicate significant differences between treatments according to Tukey's HSD test (P≤0.05).

1). This is because extra depth allows more growing media to be placed over the top of the bulbs, thus allowing adequate stem roots to develop. Planting depth showed that stem root of deep planting at 25 cm was higher or similar and never lower than shallow planting at 5 cm across the studied cultivars (Figure 2). In addition, the stem root fresh weight of total roots for deep planting at 25 cm was 68% higher while for shallow planting at 5 cm was lesser than 50%. Cultivar, Orienpet lily 'Maytime' had higher stem root system than both L.A. cultivars, 'Fangio' and 'Pavia' (Table 2, Figure 2). A higher root system for Orienpet 'Maytime' resulted in larger leaf area and plant height compared to L.A. lilies.

Large root system improves nutrient uptake and the adaptation of plants to environmental stresses. For example, mother corms of saffron (*Crocus sativus*) harvested from 4-year-old farm at 20 cm soil depth were able to alleviate the adverse effects of freezing stress (-10 and -20°C) compared to 1-3-year-old at planting depths of 10-15 cm (Koocheki & Seyyedi, 2019). With dropping temperature, electrolyte leakage in leaf and whole underground part significantly decreased with increasing planting depth (10, 15 and 20 cm) (Koocheki & Seyyedi, 2019).

Flower quality

Flower quality can potentially influence commercial cut flowers appearance and marketing. Lily flower quality components include number of flowers per stem, color, diameter, number of days to flowering, and vase life (Woodson, 1991; Burchi *et al.*, 2010).

Deep planting showed higher flower number per stem and vase life than shallow depth (Table 3). Planting depth × cultivar interaction also revealed that 'Maytime' and 'Fangio' from 25 cm planting depth had higher vase life than those from 5 cm (Figure 3). This improvement in flower number per stem can be attributed to higher root system at 25 cm treatment (Table 2). The total root per plant at 25 cm treatment was 60% higher than the 15 cm and 67.5% higher than the 5 cm soil depth. During the postharvest assessment, floral stems were standardized with 70 cm in length across the treatments. In addition, leaf number per stem was also consistent (±4 leaves) across the tested treatments. However, stem diameter was significantly affected by soil depth treatment (Table 1). Stem diameter from deep planting at 25 cm was higher than those from 5 and 15 cm planting depth.

The main goals of cut flower growers including lilium is to increase flower growth and productivity. Although deep planting has many benefits, it could delay the bulb sprouting. In addition, when the soil has poor drainage it could cause rotting of the bulbs. In this study, bulb fresh weight was similar across the planting depths (Table 2). In addition, the number of days to flowering did not differ significatly (Table 3). The number of days from planting bulbs to flowers ranged from 94 to 96 days. For cultivars, 'Maytime' required longer period to flower (113 day) compared to 'Fangio' (76 day) and 'Pavia' (96 day). Overall, no delay or negative effect had been noticed in deep planting at 25 cm compared to the shallower depths at 5 and 15 cm. In addition, the Orienpet type lily 'Maytime' required longer production cycle (more input cost) compared to L.A. type 'Fangio' and 'Pavia'.

Flavonoids, carotenoids, betalains and chlorophylls are the primary natural pigments that controlled petal color, an important visual flower quality for lily marketing (Davies & Schwinn, 1997; Burchi *et al.*, 2010). Color coordinates are essential for visual appearance of the flower and for commercial quality. For example, high L* represents more shiny and bright petals while the a* coordinate showed a high red component (Burchi *et al.*, 2010). In this study, in term of cultivars, the petal color for 'Maytime' is white, 'Fangio' is pink and 'Pavia' is yellow. The purple-flowered petals 'Fangio' had the highest red component a* while the 'Maytime' a* and b* component (Figures 1 and 4). 'Pavia' was more yellow in color (b*) than the other cultivars. Deep planting at 25 cm had no significant effect on color analysis, L* (lightness), a* (red/green) and b* (yellow/blue) except for b* coordinates in 'Fangio' (Figure 4).

Several commercial growers including Jordanian lily producers plant bulbs at shallow depth especially when they use soilless system tunnels. This is because deep planting requires more growing substrate and nutrients supply.

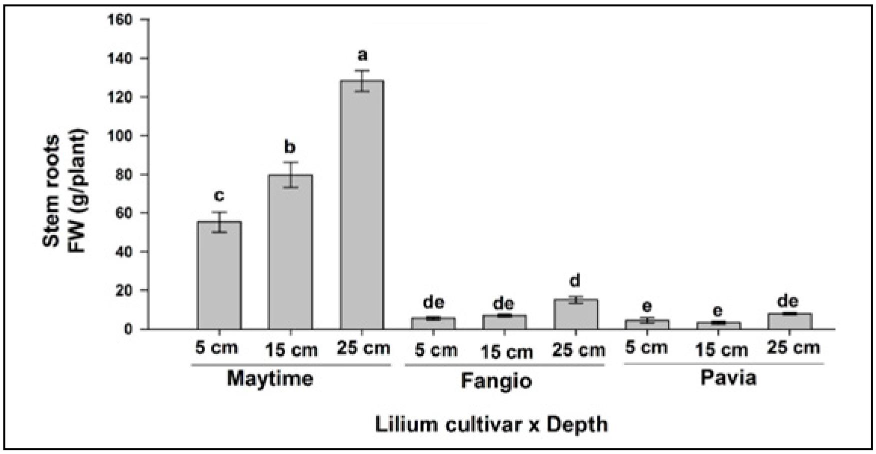

Figure 2. Stem root fresh weight (FW) of Orienpet ('Maytime') and L.A. ('Fangio' and 'Pavia') lily under different planting depth. Different letters above bars indicate significant differences between treatments according to Tukey's HSD test (P≤0.05). Amman, Jordan, University of Jordan, 2020.

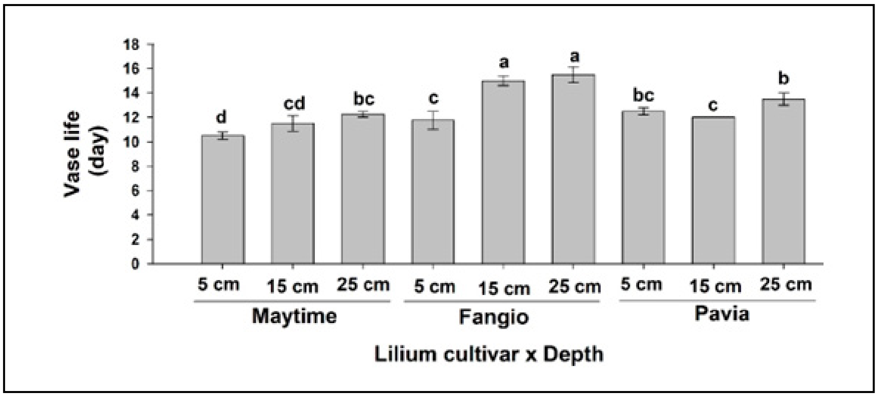

Figure 3. Vase life of Orienpet ('Maytime') and L.A. ('Fangio' and 'Pavia') lily under different planting depth. Different letters above bars indicate significant differences between treatments according to Tukey's HSD test (P≤0.05). Amman, Jordan, University of Jordan, 2020.

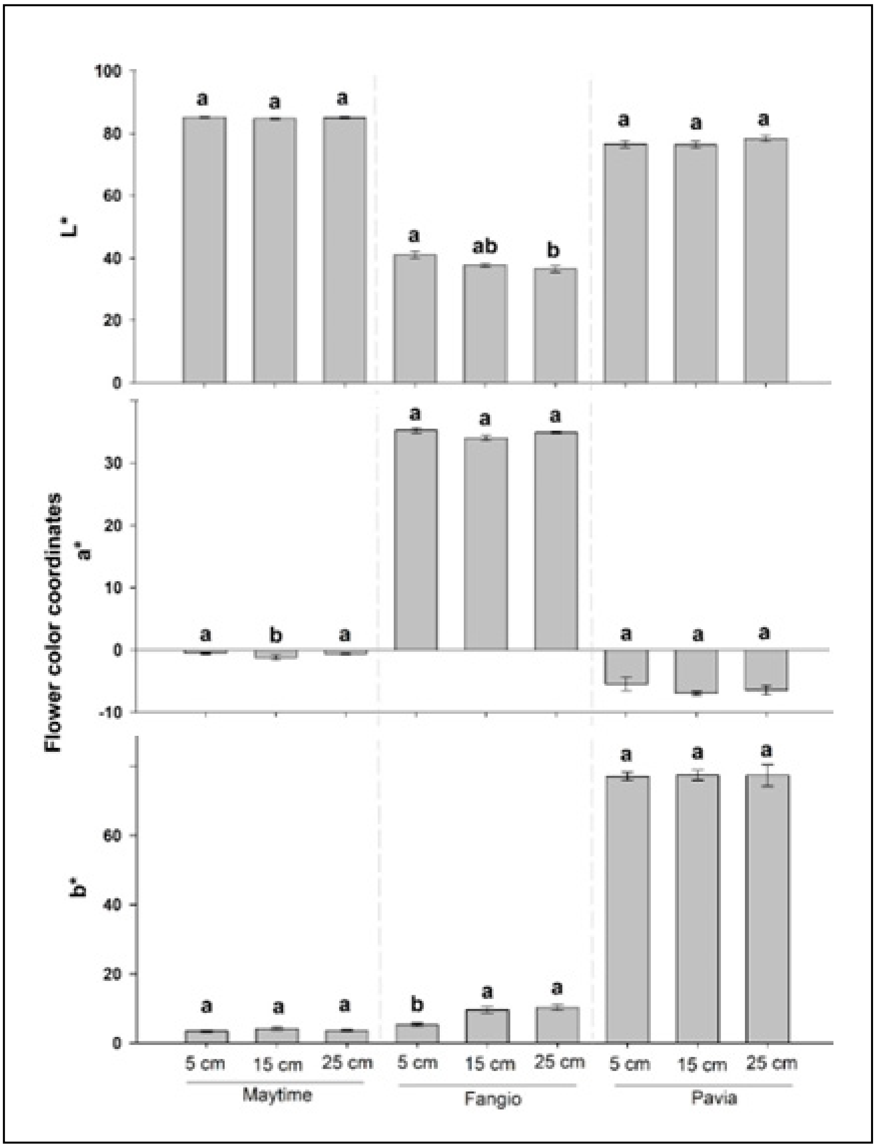

Figure 4. Flower color coordinates (L*, a* and b*) of Orienpet ('Maytime') and L.A. ('Fangio' and 'Pavia') lily under different planting depth. Different letters above bars indicate significant differences between treatments (within cultivar) according to Tukey's HSD test (P≤0.05). Amman, Jordan, University of Jordan, 2020.

The results of this study revealed that deep planting significantly incrased flower number per plant as well as flower vase life. This improvement in flower yield and quality could copensate for the additional substrate and nutrient input cost when deep planting at 25 cm is applied. Further research is warranted to estimate the input cost and total reveune of using deep planting.

In conclusion, we recommended the 25 cm soil depth for planting Orienpet 'Maytime' and L.A. 'Fangio' and 'Pavia' lilies. Deep planting at 25 cm significantly improved stem diameter, plant height, leaf area, total and stem fresh roots. Consequently, the 25 cm treatment had the highest flower number per stem. For cultivars, 'Maytime' had the highest plant height, total root and stem roots fresh weight, flower diameter and the number of days to flowering compared to 'Pavia' and 'Fangio'. Conversely, 'Maytime' had the lowest flower number per stem and vase life. Plant physiological measurements including chlorophyll content and gas exchange (P_n, g_s, and E) were inconsistent or not significant and therefore, those variables are not suitable to assess the influence of management practices on lily production and flower quality.

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